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PROCESS FOR THE PRODUCTION OF STOVE-FINISHED STRUCTURAL COMPONENTS FROM AGEING-SENSITIVE STEEL

The invention relates to a process for the production of a buckling-resistant stove-finished structural member from cold rolled and dressed strip (cold strip) from non-ageing steel with high bake-hardening potential, more particularly of more than 70 N/mm².

To achieve a high bake-hardening potential as a rule use is made of steels which contain dissolved nitrogen as well as dissolved carbon. Examples of these are unkilled steels. The storage of strips of such steels at room temperature leads even after the short time of one or two days to ageing processes which make impossible any satisfactory further processing, more particularly cold working. There is also an adverse effect on the surface texture of the cold strips.

Ageing can be caused by the diffusion of dissolved carbon and/or nitrogen. In the case of pure carbon ageing the effect of temperature on ageing time can be estimated as follows: The times t_1 and t_2 required for identical ageing effects stand in converse ratio to the associated temperature-dependent coefficients of diffusion of carbon in α iron.

In the temperature range up to 100°C we therefore have

$$t_1(T_1)/t_2(T_2) = D(T_2)/D(T_1) =$$

$$= \frac{\exp(-21.1 / (1,987 \cdot 10^{-3} \cdot T_2)}{\exp(-21.1 / (1,987 \cdot 10^{-3} \cdot T_1)} \qquad [1]$$

with $T_{1,2}$ in K.

Table 1 shows the factors calculated according to equation [1] for the delay in time of an ageing effect due to lowered temperatures. For example, in comparison with ageing at room temperature, ageing at -10°C lengthens ageing time by 62 times.

Table 1

Ageing temperature (°C)	10	5	0	-5	-10
Factor [1)]	3.6	7	14	29	62

[1)] Factor for the delay in time of an ageing effect at different temperatures in comparison with room temperature for ageing by dissolved carbon according to equation [1]

The quantity of description of the effect of dissolved nitrogen on steel ageing can be carried out similarly to the description of carbon ageing according to equation [1], using the coefficient of diffusion for nitrogen. The connection between ageing time and ageing temperature is therefore obtained as follows:

$$t_1(T_1)/t_2(T_2) = D(T_2)/D(T_1) =$$

$$= \frac{\exp(-18.33 / (1,987 \cdot 10^{-3} \cdot T_2)}{\exp(-18.33 / (1,987 \cdot 10^{-3} \cdot T_1)} \qquad [2]$$

with $T_{1,2}$ in K.

Table 2 shows the factors calculated according to [2] for the delay in ageing effect caused by dissolved nitrogen.

Table 2

Ageing temperature (°C)	10	5	0	-5	-10
Factor [2)]	3.1	5.5	14	19	36.5

[2)] Factor for the delay in time of an ageing effect at different temperatures in comparison with room temperature for ageing by dissolved nitrogen according to equation [2]

It is an object of the invention to provide a process for the ageing-free further processing of cold strips of an ageing-sensitive steel with high bake-hardening potential to produce a stove-finished structural component.

To resolve this problem the invention provides a process as set forth in claim 1 or a process as set forth in claim 3.

In the process according to claim 1 the ageing of dressed cold strip is suppressed by its storage at low temperature. In the alternative process set forth in claim 3, due to the bake-hardening effect triggered thereby the stove-finishing performed shortly after further shaping processing prevents the ageing of the cold strip dressed shortly prior to further processing.

To make use of the positive effect of a lowering of the surrounding temperature during the storage of cold strips, the storage temperature T in K (degrees Kelvin) can be estimated as follows, in dependence on the planned storage time in hours:

$$T = 9225 / (31.48 - \ln (48/t)$$ [3]

Equation [3] follows from equation [2] and relates to a steel which can no longer be satisfactorily processed, due to nitrogen ageing after exceeding a storage time of more than 2 days at 20°C. In the case of ageing by both elements, it is enough to allow for nitrogen only, due to the lower diffusion speed of carbon in comparison with nitrogen.

As an example, the change in material properties due to ageing at different temperatures was measured on a cold strip of a steel containing 0.003% C, 0.27% Mn, 0.003% Si, 0.007% P, 0.006% S, 0.046% Al, 0.001% N and Cu+Ni+Cr < 0.1% (values in % by weight). After hot and cold rolling the steel was galvanised in a continuous fire-coating installation with a maximum annealing temperature of 820°C and then subjected to 1.5% dressing. The difference between the upper and lower yield points ($R_{eh}-R_{el}$) was evaluated from the tensile test as a measure of the risk of stretcher strains.

Fig. 1 shows the development in time of $R_{eh}-R_{el}$ at room temperature, 60°C and 100°C. Value $R_{eh}-R_{el}$ = 2 N/mm² can be regarded as the limit value for fault-free processing. With higher values than 2 N/mm² the occurrence of stretcher strains must be expected, since there is a marked drop in load in the stress/strain curve.

In Fig. 2 the associated time for reaching the value $R_{eh}-R_{el}$ = 2 N/mm² is plotted Arrhenius-fashion for each temperature. As in the case of all diffusion-controlled processes, the result in good approximation is a straight line.

The effect of a further lowering in temperature can be determined by lengthening the straight line with the values from Table 3.

Table 3

Ageing temperature [°C]	30	20	5	0	-5	-10
Ageing time [3] [h]	56 (2,3 days)	174 (7,3 days)	1118 (6,7 wks)	2170 (13 wks)	4320 (26 wks)	8830 (53 wks)

[3] Time for reaching Reh-Rel = 2 N/mm^2 with different ageing temperatures from the example of steel A (Arrhenius dependence, Fig. 2)

While the critical value of ageing resistance is reached at 30°C and 20°C after 2 and 7 days respectively, processing free from stretch strains is ensured up to 13 weeks at 0°C and even up to one year at -10°C.

Table 4 lists the mechanical values of the steel, its 0.2% proof stress ($Rp_{0.2}$), tensile strength (Rm), elongation (A80), elongation without necking (Ag), the r value and its bake-hardening potential BH_0, and also the contents of dissolved C and N in the starting condition.

Table 4

$Rp_{0.2}$ N/mm^2	Rm N/mm^2	A80 %	Ag %	r value	BH_0 N/mm^2	$C_{diss.}$ ppm	$N_{diss.}$ ppm
215	310	44	23.5	1.75	73	30	< 1

By the use of one of the two processes according to the invention a steel which has high contents of dissolved carbon and/or nitrogen and is not ageing-resistant at room temperature can be further processed without the risk of surface faults even after a prolonged storage period.

The advantage of the process according to the invention lies in the utilisation of a high bake-hardening potential to produce steels from which structural components can be made which have higher buckling resistance in comparison with conventional bake-hardening steels resistant to ageing at room temperature.